Information Crossfile

The costs of invasion

Resource managers face the difficult task of picking and choosing which ecological problems, among many, they can actively address. In a crisis-laden field, how can we prioritize resource needs? Where do invasive species rate among the myriad threats facing the National Park System? Two frequently cited articles provide justification for moving invasive species management near the top of the list. A 1998 study of threatened and endangered species in the United States found that alien species are second only to habitat destruction and degradation as a threat to imperiled species (Wilcove et al. 1998). The authors quantify threats to imperiled species in the United States. In summation, exotics affected 57% of plant species and 39% of animal species analyzed overall, and the figures jump to nearly 100% when considering only Hawaiian species. Investigators also found that invasive species affect aquatic systems in the West in particular.

In addition, Pimental and others (2000) tally the economic costs of biotic invasions at approximately $137 billion annually in the United States alone. In the article "Environmental and Economic Costs of Nonindigenous Species in the United States," the authors combine the losses and damages caused by alien invasive species with the costs of control for exotic plants, vertebrates, invertebrates, and microbes to obtain a rough estimate of the total cost. Often no data concerning the costs of an invasion were available; therefore, the true cost of invasive species almost certainly is underestimated in this study. However, information from these two studies shows that allocating funds to invasive species management projects has both high economic and ecological value. —R. Harms, graduate student, College of Environmental Science and Education, Northern Arizona University, Flagstaff.

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Trade policy and prevention of nonnative species invasions

Approximately half of the invertebrate and disease pests imported into the United States come in on live plants; most of the other half of pests comes in on raw wood and wood packaging. Quantities of these items are increasing with increasing trade. Horticultural imports are not only risky because of the small (1–2%) but highly significant numbers of invasive exotics that escape, but also because of the hitchhikers on these imports. Because biological invasions are rarely reversible, prevention seems desirable. However, the current process in the United States and most other countries is to try to balance native biodiversity protection and trade promotion. The rules established by the United States and its trading partners are based on the premise that phytosanitary regulations should not be more restrictive than necessary to achieve a country's chosen level of protection. Furthermore, the World Trade Organization regards phytosanitary measures as a potentially unjustified barrier to free trade. Therefore, the burden of proof is placed on advocates for the prevention of exotic species invasions and the protection of native biodiversity.

Recent articles detailing the major pathways of pests entering the United States may be useful for resource managers in achieving a broad understanding of invasions and options for improvement in U.S. strategy, policy, and techniques for prevention. Campbell (2001) examines U.S. and international policies governing the structure and implementation of invasive species prevention programs, and recommends approaches for addressing the huge consequent problems that arise for protection of biodiversity. Campbell and Schlarbaum (2002) provide much detail on the biological outcome of prioritizing trade above protection—which results in forests, especially those of eastern United States, dying because of introductions of damaging foreign pests and diseases. Campbell and Kriesch (2003) review and outline pathways for invasive species into the United States. —L. Loope, Haleakala Field Station, USGS, Pacific Island Ecosystems Research Center, Maui.

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Before and after eradication: considering the ecosystem effects of invasive species

Most land managers in the National Park Service view the removal of invasive exotic species from natural landscapes as a top priority. However, as invasive species become pervasive elements of the communities they invade, their relationships and interactions with native species become established and complex. In the article "Viewing Invasive Species Removal in a Whole-Ecosystem Context," the authors urge a careful analysis of invaded systems before removing a species.

Eradication projects can have unintended consequences on native systems. For instance, the removal of feral herbivores at Santa Cruz Island (Channel Islands National Park, California) led to an increase in fennel *(Foeniculum vulgare)*, starthistle *(Centaurea solstitialis)*, and other introduced herbs (see note following). Likewise, removing exotic prey can cause exotic predators to switch to native prey for food, as happened in New Zealand when exotic stoats (ermine *[Mustela erminea]*) increased predation on native birds and mammals after rats and possums were removed from forests. Native species also can come to rely on exotic species; for example, endangered Southwest willow flycatchers *(Empidonax traillii extimus)* often nest in thickets of invasive, nonnative tamarisk (*Tamarix* spp.).

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To avoid unanticipated, "surprise" outcomes, the authors suggest that assessment precede eradication. Specifically, food-web interactions among exotics and between exotics and natives should be investigated, and functional roles of invasive species should be identified. In addition, post-eradication monitoring should be included in a program to determine the effects of management actions on both the targeted species and the affected ecosystem. By incorporating these processes into management plans before and after eradication, an informed framework can guide invasive species management and ecosystem restoration. —R. Harms, J. Selleck, and K. Faulkner (Channel Islands National Park)

Reference

Zavaleta, E., R. Hobbs, and H. Mooney. 2001. Viewing invasive species removal in a whole-ecosystem context. Trends in Ecology and Evolution 16(8):454–459.

Editor's note: As the authors note, the removal of sheep and cattle from Santa Cruz Island led to the recovery of native Bishop pine *(Pinus muricata)*, but also to an apparent increase in the distribution and abundance of other rare plant species. (Klinger, R. C., et al. 1994. Vegetation response to the removal of feral sheep from Santa Cruz Island. Pages 341–350 in W. L. Halvorson and G. J. Maender, editors. The Fourth California Islands Symposium: Update on the Status of Resources. Santa Barbara Museum of Natural History, California.)

Theory guides rapid response to plant invasions

Land managers have long realized that exotic species do not invade plant communities equally. Many theories have been advanced to explain these differences, but studies to investigate these theories often produce conflicting or ambiguous results. However, Davis and others (2000) have developed a new theory from empirical studies and long-term vegetation monitoring that is simple yet captivating: a plant community becomes more susceptible to invasion whenever an increase in the amount of unused resources occurs. This increase may come about through a reduction in resident vegetation (e.g., from heavy grazing, a disease outbreak, or intense flooding) or through an increase in the resource supply (e.g., during a particularly wet year or as a consequence of eutrophication). A community's susceptibility to invasion, therefore, varies over time. These pulses of resource availability also must coincide with the presence of invasive propagules such as seeds and spores, leading to the episodic establishment of invasive species.

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This theory has important implications for resource managers, in particular the required response to new invasions. In short, environments that are naturally subject to frequent fluctuations in resource availability will be invaded most often and should be a priority for monitoring and potential mitigation. Areas that experience a known disturbance or influx of resources also should be investigated. —R. Harms

Reference

Davis, M. A., J. P. Grime, and K. Thompson. 2000. Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88:528–534.

Exotic plants and restoration

The differing impacts of exotics can be confusing because exotic species pose both problems and solutions. For example, exotic species can colonize disturbed lands and alter sites targeted for restoration. On the other hand, exotic species can catalyze the restoration process and be used to reestablish site functions if native species are not available or cannot tolerate current conditions. Because of this ambiguity, researchers and practitioners should look to both the scientific literature and previous restoration projects when determining the best approach for restoring a particular site.

Before beginning a restoration project, managers should identify likely plant invaders and devise strategies to minimize their impacts. The method of removing exotics also should be considered carefully because sensitive species may affect what managers can and cannot do at a site. In addition, some sites will require continuous maintenance, so long-term management costs should be evaluated. Moreover, various exotic species continue to affect sites after their removal; the reversibility of these conditions and the impacts on restoration warrant further study. In some cases, intermediate plantings of species assemblages may be needed to move the site toward conditions that support the desired flora. These intermediate assemblages may need to include certain exotic species if native species cannot survive the current conditions at the restoration site. These exotics should be selected with an emphasis on their inability to persist in the system after they have served their primary function in the restoration process. Projects also should include long-term monitoring to determine whether management goals are being achieved.

Managers must be broad-thinking about exotic plants as both friend and foe.

Managers must be broad-thinking about exotic plants as both friend and foe. Nevertheless, when considering possible responses to their planned activities, resource managers must be prepared to react quickly to surprises from ambiguous exotic plants. —R. Harms

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D'Antonio, C., and L. A. Meyerson. 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. Restoration Ecology 10(4):703–713.

A web site for teachers

Web sites about invasive species abound on the Internet. Teachers will welcome one of them, http://www.nps.gov/invspcurr/alienhome.htm, that presents engaging units on the theme of invasive species for middle school classes. "Aliens in Your Neighborhood" was developed as an enhancement to required curriculum about the life sciences, especially plant science. Activities provide opportunities for students to practice math, writing, mapping, photography, and collecting and preserving plant specimens. These lessons lead students to see more closely what's going on in their immediate environment. For example, with woolly socks worn over their shoes, they take a walk at the edge of a forest or field. Then they examine the seeds stuck to the socks and understand how easily seeds are dispersed. Students plant a small piece of their sock in soil and watch what grows. This leads to investigation in many directions, such as how to identify the seedlings, how well the native species are competing with the exotics, how to reduce dispersal, and so on.

The project is sponsored by the National Park Service, funded by the Parks as Classrooms program, with additional support from the Cooperative Ecosystem Studies Unit of the University of Idaho; Washington Department of Fish and Wildlife NatureMapping Program; XID™ Services, Inc.; and CyberTracker World GIS Mapping Technologies. The author is Mark Goddard of the Nye Beach Montessori School in Newport, Oregon. Because the natural resource managers understand that invasive species are everywhere, they look to citizen scientists to help in containing the invaders. The lessons in these units are the foundation of the education of enlightened citizen scientists and, very likely, of some future professional scientists. —B. Blumberg

What's the big deal about earthworms?

We assume that earthworms are good for our gardens and soil. But consider the natural ecosystems in the National Park System, for example national parks in the upper Midwest. Recently researchers have reported in various articles that invasive, exotic earthworms from Europe and Asia (e.g., *Lumbricus rubellus*) can have a deleterious impact on the forest floors of northern temperate forests.

The most dramatic effect of earthworm invasion is the loss of the forest floor at previously undisturbed sites.

See "Information Crossfile" in right column on page 31

baseline information and viable tools for assessing and prioritizing weed management and restoration activities is critical to ensure the best use of limited personnel and financial resources. As such, new tools and conceptual frameworks are being developed to improve weed management and habitat restoration capabilities. These contributions represent a significant step forward in addressing the invasive plant issue, yet without further augmentation of resources (personnel and funds), invasive weeds will remain a prominent threat to the resources of our national parks.

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"Information Crossfile" continued from page 9

Under natural conditions—without earthworms—fallen leaves decompose slowly, creating a spongy layer of organic duff, which is the natural growing environment for native woodland ferns and wildflowers. The duff layer also provides habitat for ground-dwelling animals and helps prevent erosion (Holdsworth et al. 2004). Invading earthworms eat the leaves that create duff, thereby eliminating the layer and decimating forest floors. Mature trees survive, but saplings, ferns, and flowers perish.

Although beneficial in many urban and agricultural settings, earthworms create a soil of a certain consistency, which can have adverse effects in northern forest ecosystems by actually compacting soil. Compaction decreases water infiltration, and less infiltration combined with less duff results in increased surface runoff and erosion (Holdsworth et al. 2004).

In addition to changing the structure of soil, exotic earthworms alter the chemistry of soil. Invasion alters the location and nature of nutrient cycling in soil profiles and changes total carbon and phosphorus pools, carbon-nitrogen ratios, and the loss and distribution of different phosphorus fractions. The organism factor in soil formation also is affected by earthworm invasion: the distribution and function of roots and microbes is significantly disturbed (Bohlen et al. 2004).

The take-home lesson: Exotic earthworm invasion is a significant factor that will influence the structure and function of temperate forest ecosystems over the next few decades. Researchers have little doubt that earthworms are invading new habitats in northern forest ecosystems and that such invasion constitutes a potentially important change in these systems over wide geographic areas (see pages 61–62). If earthworm invasion is an important factor influencing patterns of nutrient cycling and loss in northern forests in the coming decades, then regional evaluations of forests will need to consider the presence or absence of earthworms along with other important drivers of those processes, such as pollution, climate, or underlying soil characteristics (Bohlen et al. 2004). —K. KellerLynn

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